AFTER THE FLUSH

FARM SPREADING

COMPOSTING

HEAT PROCESSING

IRRADIATION

? MARKETABILITY

? EMOTIONAL

? COST

? ENVIRONMENTAL IMPACT

Science Technology & Society

ACCESS NETWORK

AFTER THE FLUSH

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ISBN 1-895350-61-1
Printed and Bound in Canada

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The Science, Technology and Society Series

STS is an international science education movement. It represents the first significant change in the science curriculum in 25 years. The STS concept strives to broaden the scope of science education by integrating into science curricula accurate presentations of the nature of science, the nature of technology and the interactions of science and technology with each other and society. The video series provides illustrative examples of the relationships between science, technology and society.

The STS connections describe products and processes; environmental and ethical issues relating to the interrelationships among science, technology and society; how scientific knowledge develops and the influence of society on scientific and technological research; and science and technology related careers. The contexts are meant to be relevant to students' lives and also prepare students for life in a rapidly changing society in which science and technology play an important role.

To the Teacher

There's good news, and there's bad news. Every new technology, medical treatment, business enterprise, or construction project comes with its own list of positives and negatives: benefits and risks.

This video program is aimed at students in Grades 11 and 12 who are studying chemistry, biology, physics, or integrated sciences. It may also be of interest to grade 10 students. The program gives viewers a unique perspective on **risk/benefit analysis**, showing how the process can be applied to the problem of sewage sludge disposal. Although the subject matter is presented in a humorous way, the underlying message is serious.

Waste management is a common dilemma in urban areas, and therefore a problem that may be applicable to the viewers' own towns or cities. Viewers will see that it is important to look at the situation from different perspectives, and to analyze the associated risks and benefits. Whether we're talking about construction of a dam, location of a landfill site, or any number of other contentious issues, proponents and opponents all have strong opinions and convincing arguments. Issues are usually not simple and do not lend themselves to definitive solutions. Right and wrong depend on your point of view, and most "solutions" are a compromise.

Besides the broad topic of risk/benefit analysis, teachers can use the video as a resource for studying the science involved in sewage treatment. This is a natural biological process that relies on oxygen, gravity, aerobic and anaerobic bacteria, temperature controls, and the conversion of organics to biogas. Sewage sludge has a chemical composition that makes it valuable as a fertilizer, but it also contains disease-causing micro-organisms.

Objective

The video demonstrates the complexities of effective planning and decision-making. It shows the importance of weighing quantitative and qualitative risks and benefits before embarking on any new project. Viewers should be encouraged to become informed about issues, and to use their knowledge to arrive at rational decisions.

Overview of *After the Flush*

The king in our mythical kingdom would rather pass the hours exercising and improving his golf game than dealing with serious issues. However, his advisor insists that one particular problem must be confronted: the kingdom is producing too much sewage sludge, and is running out of places to dispose of it.

The king and advisor realize there are different options in disposing of sewage sludge, and they must make a decision about which route to take. They decide to rate each option in terms of fixed criteria. The three criteria are:

- **cost,**
- **environmental impact,** and
- **marketability of the end product.**

Later, they add a fourth criterion: "Emotional Response".

They narrow down their choices of disposal methods to four options. The four options are:

- **farm spreading,**
- **composting,**
- **heat processing,** and
- **irradiation.**

Four representatives of the different options come to the palace. Each one argues in favour of a particular option, and tries to persuade the king and advisor to choose that method of disposal. After all the presentations have been made, the king is left with the realization that there is no such thing as a simple solution.

Background Information

Risk benefit analysis can be applied to any number of problems, but this video deals with the disposal of sewage sludge ... a problem which should be seen in the larger context of waste management.

Only two or three generations ago, most people lived on farms. Today, the majority of the population lives in cities. One result of this demographic change is that we have great amounts of garbage to dispose of, within concentrated areas.

The subject of waste disposal is fraught with emotion and controversy. There is no ideal spot on this planet to locate a landfill, and we desperately need more sites. With dumps across Canada getting close to capacity, people are looking at alternative ways to deal with garbage. Each alternative has advantages and disadvantages.

Sewage sludge is part of urban waste, and its safe disposal is part of the on-going problem of waste management. When hundreds of thousands, or millions, of people live together in a city, the amount of sewage sludge quickly adds up.

Where Does Sewage Go?

Sewage treatment involves separating solid from liquid waste. Waste water from the city is flushed through pipes to the sewage treatment plant. First it flows into grit tanks. Air is circulated to keep organic matter suspended while sand and gravel settle to the bottom. This is scraped out and taken to the landfill. Paper, sticks, plastics and debris that float to the top are also taken to the landfill.

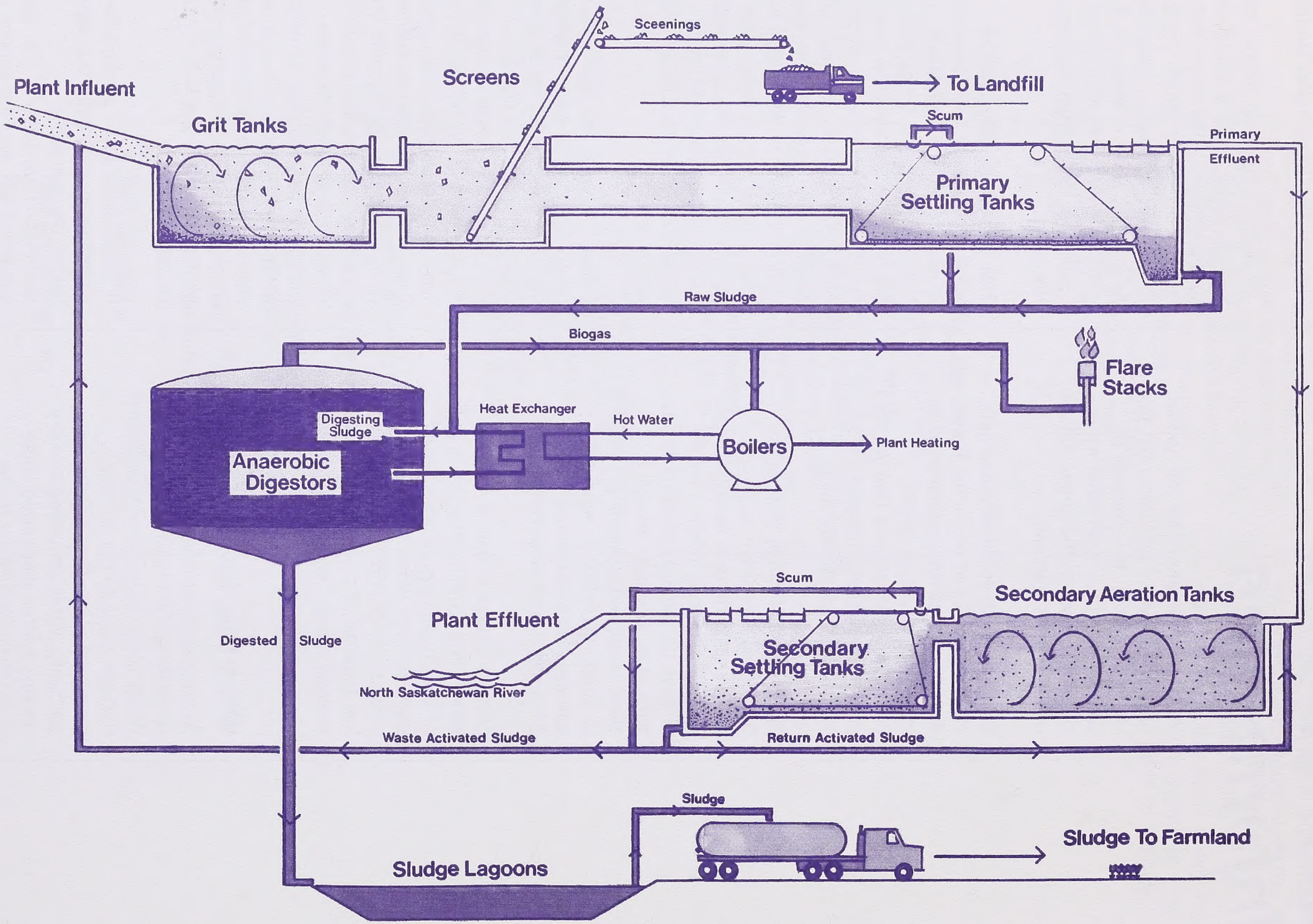
The waste water now passes into settling tanks. Organic matter settles to the bottom of the tanks and forms a substance called "sludge". Oil, grease, and lighter materials float to the surface. Mechanical scrapers collect this sludge and scum from the bottom and top of the tanks.

This process is called primary sewage treatment. The water, which is now called primary effluent, flows into aeration tanks for secondary treatment. In the aeration tanks, micro-organisms feed on organic matter in the water. The water then flows into final clarifiers (settling tanks) before it is discharged back into the river. This treated water has 96 to 97 per cent of suspended matter and organic pollutants removed. The process takes about twelve hours.

Organic material that has been removed from the water is piped into a machine called an anaerobic digester. Inside this digester, anaerobic bacteria go to work on the sludge. (Anaerobic means they can work without oxygen.) Decomposing material goes through certain stages. First, acid-producing bacteria break down the organics into short-chain (volatile) fatty acids. Methane-producing bacteria then convert these acids to biogas. Biogas, which contains methane, is collected and used to heat the sewage treatment plant. Any excess gas is burnt off at the plant.

It takes about 15 to 20 days for sludge to pass through the digester. During the process of decomposition, some of the liquid separates out, and the volume of sludge is reduced by one half.

A City Waste Water Treatment Plant



Digested sludge is pumped to open lagoons, where it remains for several years. A city of half a million people can produce about 20,000 tonnes of dry sludge per year.

The sludge is high in phosphates and nitrogen, and therefore has value as a fertilizer. However, its use must be regulated. Treated sludge still contains harmful micro-organisms, including bacteria, viruses, and intestinal parasites. Depending on the city, the sludge may also contain heavy metals and other toxic wastes.

Part I: Sewage Sludge Disposal Methods

Farm Spreading

Farm spreading is a process used by many cities to dispose of large amounts of sewage sludge. During the growing season, tanker trucks remove sludge from the lagoons in a slurry of about ten per cent solids, and transport it to farmland. The trucks then spread sludge over the fields.

The farmer must work the soil within 24 hours of spreading, in order to bury the sludge. For three years, the field cannot be used for root crops or grazing, because of the possible transmission of pathogens. However, it is fine for growing grain crops. Pathogens will biodegrade in the environment. After three years, they will have reached the end of their life cycle, or will have been destroyed by sunlight or other bacteria. At this point, the land can be used for any crop.

Sewage sludge can only be spread on farmland under certain conditions:

- soil must be workable (not frozen)
- land must be relatively flat, to prevent run-off
- groundwater must be a good depth under the soil, to reduce the risk of contamination
- land must not be used for root crops or grazing for three years
- sludge must not have high concentrations of heavy metals or toxic chemicals.

Advantages

Farm spreading is an environmentally sound use for sewage sludge. The sludge is not only disposed of, but it actually improves the quality of farmland. As well as fertilizing the soil, sewage sludge acts as a soil conditioner. Organic matter in sludge improves the soil's capacity to hold water.

Disadvantages

Although this program is popular with farmers, the land adjacent to a city is quickly used up. Sludge must then be trucked longer and longer distances away from the sewage lagoons, and this adds to the cost.

Farm spreading is very dependent on weather. If the ground is too wet, trucks can't get onto the fields. Because the schedule for spreading cannot be determined in advance, farmers often wait several weeks for a shipment, and sometimes must wait until the next season. They put up with this inconvenience because the sludge is free. It is not possible to charge farmers for the sludge, so

the city must assume transport and spreading costs.

The schedule for spreading is limited to the growing season. The program can handle only about 50% to 70% of the city's total sludge output.

There are some aesthetic and health concerns associated with farm spreading. However, these are not serious. Odours can be kept to a minimum if the soil is worked immediately after spreading. Careful selection of sites means that run-off problems and groundwater contamination can be avoided.

Sludge with high concentrations of heavy metals or toxic chemicals may not be suitable for spreading.

Composting

Composting is a natural process of decomposition, and is becoming more popular as a method of waste disposal. The final product of the composting process is humus, which is the organic constituent of soil formed by decomposed plant and animal material. Composting is going on all the time in the wilderness; matter rots, due to the activities of living unicellular organisms such as bacteria, and multicellular organisms such as insects and worms. In backyard or large urban composting facilities, this natural process is speeded up by keeping the compost moist, and turning it frequently so that wastes are exposed to the air.

Rapid decomposition also requires a proper balance between carbonaceous materials and nitrogenous matter. This is commonly referred to as the carbon/nitrogen ratio, or the C/N ratio. The ideal C/N ratio for effective composting is 25 parts carbon to one part nitrogen. The final humus product should have a C/N ratio of about 10 parts carbon to one part nitrogen.

The carbon ratio of some common materials to one part nitrogen is as follows:

grass clippings	25
oak leaves	50
manure	23
vegetable scraps	25
pine needles	100
sawdust	150 *to* 500

A large scale urban composting facility will require that waste materials be monitored to achieve the right proportions of carbon to nitrogen and moisture. Sewage sludge, because it is low on carbon, can comprise only a small portion of the total waste product. The waste must be at least six parts carbonaceous material to one part sludge.

When microbes digest carbon compounds, the carbon is converted to carbon dioxide, or oxidized. Part of this energy is given off in the form of heat. Energy is therefore a by-product of decomposition. Certain types of bacteria thrive in warmer temperatures, and it is generally true that matter will decompose more rapidly in warmer temperatures. High temperatures also kill pathogens. For reasons of efficiency and hygiene, large scale composting should be carried out in warm climates or in an indoor facility with temperature control.

The complexity of the composting process depends on the quantity and types of waste that are being composted. Grass clippings and other garden wastes are relatively easy to compost. With moisture, time, a little added soil, and an occasional stir to let in oxygen, these materials will decompose.

Many other waste products could also be handled in a composting facility. When a city initiates large scale composting, homeowners and businesses are asked to separate their garbage into wet and dry bags. Materials in the dry bags are recycled if possible, and the wet bags go to the composting plant. Wet bags from residential areas can include the following:

- kitchen waste
- wet and soiled papers
- diapers and sanitary products
- pet wastes

Non-residential products which can be composted include the following:

- animal manure
- waste from feed lots
- waste from packing plants
- wood chip waste
- newspaper products
- phone books
- sewage sludge

Some of these materials include pathogens, which are undesirable in the final product. All disease-causing organisms such as bacteria, viruses and intestinal parasites *should* be killed in the composting process. This means that the waste must be kept at 55.9 degrees Celsius for 72 hours.

Large scale composting is being carried out in some cities, and other cities are studying the possibilities. Cities in the southern United States, such as Los Angeles and Dallas, have a climate that makes outdoor composting practical. Penticton, B.C., composts waste outdoors, but only March to mid-December. Because Penticton is a small city (about 50,000 people), the volume of waste is not great.

Advantages

Organic materials take up a great deal of space in a landfill, and large scale composting offers an effective alternative. Much of a city's garbage can be disposed of through composting, and the end product can be put to use as a soil enricher, possibly in land reclamation projects. Composting is a natural process, and is an environmentally friendly option for disposing of wastes.

Disadvantages

Although composting is a good method for disposing of many waste products, it cannot handle large quantities of sewage sludge. It is therefore not a solution to the sewage sludge disposal problem. As a method for disposing of other organic wastes, composting has some drawbacks.

Canada's climate is cold for much of the year, and, with the exception of composting yard wastes in summer, large Canadian cities do not have the outdoor composting option. Indoor composting facilities involve a great deal more expense.

Any large scale composting operation will have problems with odours. A composting facility should therefore be located well away from residential areas. Although an indoor plant may be designed so that odours inside the plant are not released into the air, there are still odours from raw waste before it enters the plant.

Pathogens are also a concern. The product can be used as a soil conditioner, but there are restrictions on its application. Most cities do not offer compost for use by the general public because of the possibility that some pathogens may have survived the composting process. The product is typically used by spreading it in forested areas to enrich the soil, or

by using it in land reclamation at old mining sites.

Heavy metals and toxic chemicals in sludge can pose a problem. If these are present in the raw ingredients, they will still be present in the humus. Effects on the environment can be minimized by dispersing the composted material over a very wide area.

Part I: Suggested Activities

1. Sewage effluent is sometimes used to irrigate farmland, by spraying, sprinkling, or simply pumping it onto the fields. Areas that use effluent irrigation report crop yields 20% higher than areas using local surface water. Most harmful micro-organisms are killed by exposure to strong sunlight, high temperatures and dry weather. What are the advantages and disadvantages of irrigating with effluent?

   Advantages

   - Less need for costly fertilizers
   - Less costly to use untreated water for irrigation instead of drinking water

   Disadvantages

   - Effluent sometimes contains high concentrations of salts, which will accumulate in the soil and make it less productive.
   - Some micro-organisms may survive. Effluent cannot be used on crops which are eaten raw, or on crops such as corn, where the leaf structure could harbour micro-organisms.
   - Run-off from effluent could pollute groundwater or nearby bodies of water. Land must be carefully selected so that the effluent will not pollute the environment.

2. Experiment with composting, comparing different organic materials to see how readily they break down. An example would be to compare a pile of grass clippings with a pile of pine needles. Introduce variables such as temperature, light, air and moisture, and observe their effects.

3. Start a composting project at school, by composting all scraps from the cafeteria and from student lunches. Yard wastes from the school grounds could also be included.

4. Investigate the sewage sludge disposal methods in your community. Is the sludge being handled in a responsible manner? Is there a problem with excess sludge?

5. The characteristics of sludge will determine whether or not it is suitable for land application. The typical composition of municipal sludge in Alberta is shown in the table on the following page.

Characteristics of Sludges

Composition of Alberta Sludge as Percent of Dry Weight (unless otherwise noted)*

	Min.	Max.
Solids	1.0	20
TKN* **	1.0	11
Ammonia Nitrogen	0.02	4.1
Phosphorus (total)	0.25	2.3
Calcium	1.2	6.6
Magnesium	0.37	1.7
Sodium	0.002	3.4
Potassium	0.17	1.1
Iron	0.17	2.5
Manganese**	80	1000
Zinc**	390	1400
Copper**	280	1300
Lead**	50	1750
Nickel**	16	100
Cadmium**	4	20
Chromium**	22	1700
Boron**	7	33
Mercury**	1	6

* Sludge is dried to remove all water before analyses are done.

** Parts per million on a dry weight basis

*** Total Kjeldhal Nitrogen

Sludges may also contain disease-causing viruses, bacteria and protozoan and helminthic (worm) parasites.

Which components can be used by plants as nutrients?

Which components are considered to be heavy metal toxic wastes?

Which component could potentially harm human health if incorporated into a food crop from soil treated with sludge?

NOTE: Kjeldhal Nitrogen measures ammonia plus organic nitrogen. Ammonia Nitrogen can be subtracted from TKN to arrive at the component for organic nitrogen.

SOURCE: *Sewage as a Resource*, Alberta Environment.

Part II: Sewage Sludge Disposal Methods

Heat Processing

This process for treating sludge is also sometimes referred to as heat drying. It takes place inside a building, and uses heat to reduce the sludge into a dry, stable product. The heat is produced by burning methane, natural gas, or propane. *(See illustration, page 11)*

Wet sludge is brought into the plant by augers, or on a conveyer belt. Inside the drying chamber, a radiant plate is heated by burners. The plate can reach temperatures of 1200 degrees Celsius.

Gas and steam from the sludge are taken off separately, so that emissions from the processing are not released into the atmosphere. The gases are incinerated, and the vapour is condensed. Waste water from this condensed vapour is sent back to the sewage treatment plant.

The resulting product is a very dry substance, which looks and feels like hard granules of dirt. It is odourless and free of pathogens. Eighty to ninety per cent of the water content has been removed, so the quantity of sludge is greatly reduced. Heat processed sludge is a relatively inert product that does not break down readily in water. Over the years it may add some nutrients to the soil, but it does not have real value as a fertilizer.

Advantages

Heat processing is an indoor option, and is therefore not restricted by local climate conditions. By removing about 90% of water from the sludge, this process greatly reduces the volume of sewage sludge, so there is far less product to dispose of.

The very high temperatures used in heat processing ensure that all pathogens are killed.

Emissions from the process are treated within the facility, so there is no release of waste products into the atmosphere. If a heat processing plant is located right at the sewage lagoons, there are no added odour problems.

Disadvantages

Initial costs for constructing the plant are high. Once the plant is operating, there are continued costs for fuel to heat the burners. Because heat processing depends on very high temperatures, these fuel costs would be significant.

Although emissions from the sludge are contained within the plant, there will be emissions from the burners themselves, which are vented separately.

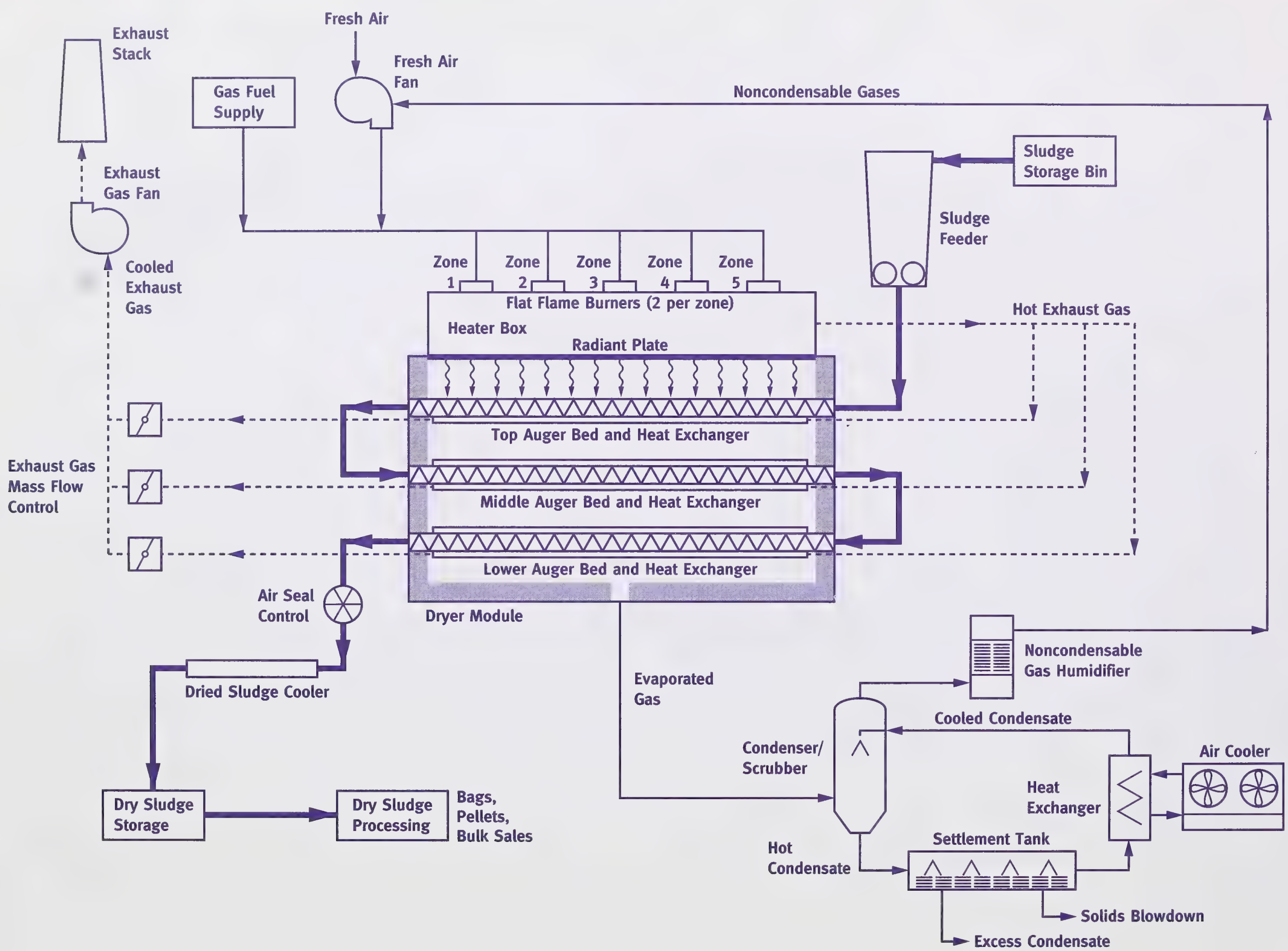
There is no market for the granules of dried sludge; however, finding a place to dispose of them should not be a problem.

Irradiation

Irradiation of sewage sludge is a new concept in North America, although it has been practised in Germany for some time. The process of irradiation has been around since the late 1940s, and Canada has a great deal of expertise in this area.

Irradiation is used extensively in industry, in the production of pharmaceuticals, pharmaceutical

Radiant Plate Dryer–Process Model



supplies, medical supplies, cosmetics, and many other products.

Irradiation is also used in hospitals to sterilize medical equipment and supplies, and to disinfect blood products for patients with low immunity. Radiation therapy is used to treat some cancers. Nuclear magnetic resonance imaging is a diagnostic procedure which employs radiation.

For many years, irradiation has been seen as a potential method for preserving food, by slowing the growth of moulds and bacteria. This use, however, has not been widely accepted. Many food packages are irradiated as a method of sterilization, as are wine corks.

Waste disposal is a potential new market for irradiation plants. As well as processing sewage sludge, irradiation could be a way to sterilize international waste from air and sea ports, and to safely dispose of medical wastes.

How It Works

Irradiation technology is fuelled by cobalt 60, a radioactive isotope. Cobalt, as mined from the earth, is a natural metallic element. It is called cobalt 59 because it has an atomic mass of 59. Thin pencils, or rods, of cobalt 59 must be treated in a nuclear reactor. Inside the reactor, they are bombarded with neutrons for a period of two or three years. At the end of this time, about 10% of the cobalt 59 atoms have been transformed into cobalt 60, and the rods are ready for use.

$$^{59}_{27}\mathrm{Co} + ^{1}_{0}\mathrm{n} \rightarrow ^{60}_{27}\mathrm{Co} + \Upsilon$$

Cobalt 60 emits gamma rays — a form of high energy electromagnetic radiation. The usefulness of radiation depends on its ionizing power and penetrating power. Gamma rays can easily penetrate any substance, with the exception of several centimetres of lead or very thick concrete. When the gamma rays penetrate a substance they create electrically charged ions which break up the molecular structure of organisms within the substance. Because of this chemical change, the organisms are unable to reproduce, and they die.

Cancer cells are more active metabolically than normal cells. For this reason, cancer cells are more susceptible to damage from ionizing radiation. In cobalt radiation therapy, the cobalt source is swung around the body in a circular arc, with the beam focused on the cancerous tumour. The tumour receives gamma radiation continuously, while surrounding healthy tissues are only briefly exposed to radiation. Gamma rays alter cancer cells so they are unable to reproduce.

The most widespread use of gamma radiation is in sterilizing products. Because gamma rays have such high penetration power, they can sterilize a product right through the packaging.

Gamma radiation does not make the product radioactive. It is safe to handle immediately after irradiation. No nuclear wastes result from the irradiation process. When cobalt 60 rods lose their strength, they are replaced. The old rods are taken back to the nuclear plant where they can be charged up again for re-use.

Irradiation of Sewage Sludge

Before it comes into the irradiation plant, sewage sludge is spun in a centrifuge to remove some of the water and then air-dried. Between 40 and 50 percent of the moisture should be removed prior to

irradiation. Sludge is taken in on a conveyer belt. The cobalt 60 rods are raised from their water storage tank, and the sludge is exposed to gamma radiation. Irradiated sludge leaves the plant on the conveyer belt and is bagged for sale.

All pathogens are killed when the soil is irradiated. Because sludge is exposed to the radiation for only a certain length of time, some vegetative bacteria will survive the process. This means that the end product is not completely inert. Beneficial bacteria produce organic compounds which inhibit the growth of disease-causing microbes. These bacteria allow the irradiated sludge to maintain a healthy microbial balance so that the product cannot easily be contaminated.

Irradiated sludge is a dry, disinfected, soil-like fertilizer product that can be sold to gardeners, nurseries, landscapers, golf courses and farmers. It acts as a soil conditioner, similar to peat moss, and also adds some nutrients to the soil.

Advantages

A major economic advantage in this process is the potential market for irradiated sludge. The product can be packaged in plastic bags, and should have a market value of about $100 per tonne.

The irradiation plant will not affect the environment with any harmful emissions.

All the sludge can be treated, leaving no surplus of sewage sludge.

Costs of running the plant are not high. The energy expense is in replacing the cobalt 60 rods. Although this is expensive, the rods have a long life span.

Cobalt 60 shipments would take place once a year. The rods are transported inside specially designed containers able to withstand accidents, earthquakes, fires and other stresses. If one of the containers should somehow break open, the rods would present a danger only to the people retrieving them.

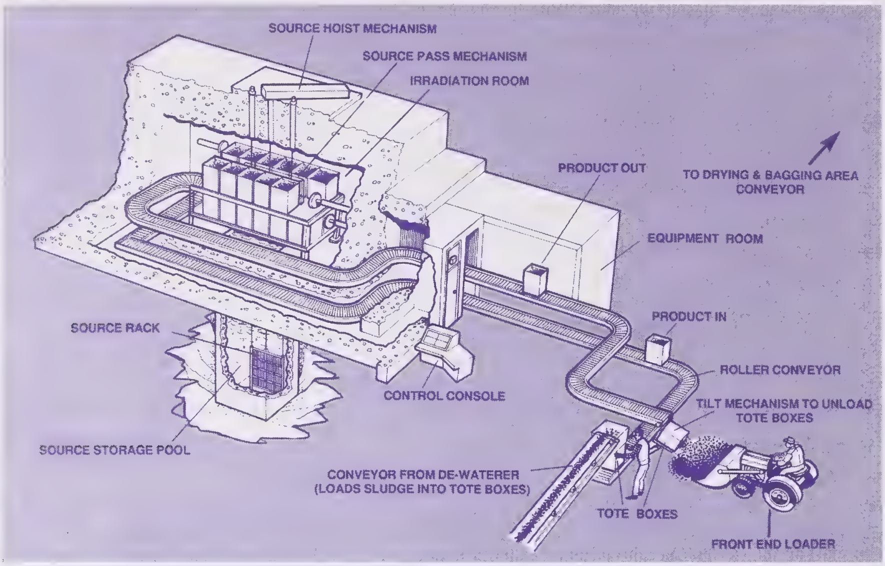
The plant itself is very safe, with concrete walls almost two metres thick. Water in the storage tank absorbs gamma rays but does not retain them. The water is safe to drink. In the very unlikely event that a plant broke apart, the only danger would be in actually handling the cobalt 60 rods. Workers wearing protective gear would have to do this.

Disadvantages

The public is wary about any process which involves nuclear energy and radiation. Although nuclear technology is used in hospitals and many industries, it is possible for people to ignore such small facilities. A plant to treat sewage sludge would be larger than the typical hospital irradiation unit, and people are fearful of larger scale nuclear technology. The nuclear disaster at Chernobyl, in Ukraine, has increased people's fears about the industry.

Before sludge is taken into the irradiation plant, it has to be de-watered and then air dried. Air drying requires space where the sludge can be spread out in the open, and turned. This is not possible in cities that experience heavy amounts of rainfall and high humidity. In these areas, all the de-watering would have to be done mechanically.

Nordion Irradiation Plant



As with the other methods, irradiation does not affect the heavy metal or toxic chemical content in sewage sludge. Cities that have toxic chemicals and/or high concentrations of heavy metals in their sludge would not be able to offer the product for sale to homeowners.

Other Options

New ideas and advances in technology add a further uncertainty to the decision-making process. The four options outlined in the video are not the only possible methods for dealing with sewage sludge, but they are the strongest contenders. There are, however, other possibilities.

One is to combine sewage with lime and cement kiln dust, and sell it as a soil conditioner. The lime should kill all the pathogens, but tests indicate that some pathogens may survive the process. This method also doubles the volume of sewage sludge, and the product is worth only about $10.00 per tonne.

A recent proposal for dealing with sludge involves blasting it through a snow-making machine, and using it as artificial snow. The company that came up with this technique claims that the quick freezing action of the snow maker kills pathogens. This technique is being studied, but there are some concerns that pathogens would survive the process.

It does, however, raise another problem. A city may invest in one method, only to find that a few months later a simpler, less costly, and more efficient method has become available.

Risks and Benefits

Problems like the safe disposal of sewage sludge do not lend themselves to easy answers. Risk/benefit analysis is one system people use in trying to grapple with complex issues. A thorough

risk/benefit analysis is a complex process, which involves measuring quantitative and qualitative risks and benefits in the hope of reaching an informed conclusion. This kind of disciplined approach helps to ensure that everything has been included that should be weighed in the analysis. People have to decide how much they are willing to risk losing—or how much gain they should insist on, in order to accept a given risk.

Although risk benefit analysis helps people to make informed decisions, it is not a black and white, absolutely accurate procedure. It is very difficult to put a value on people's lives, or on improved health. Yet these are factors that have to be included in the analysis.

The amount of risk people are willing to accept also varies widely. The public's perception of a risk may differ from the scientific community's perception of the same risk. People are more willing to accept risks if they feel that they have some control over the situation, and if the risk is a familiar one. Driving a car carries a fairly high level of risk, but people tend to look at this as part of life. It is familiar, and they feel they have some control over the situation.

"People accept risks from activities such as skiing that are about 1000 times as great as they would tolerate from involuntary hazards such as preservatives in food."

("Perception of Risk", *Science Magazine*. P. Slovic, April 17, 1987.)

While a thorough analysis takes into account as many factors as possible, there is no way of being totally accurate. When we look at a particular problem, we try to list the pluses and minuses for each alternative. But the lists can never be complete, because there are too many unknowns. Often the items are impossible to measure, and the future impact will not become really clear until far into the future.

By applying risk benefit analysis to a problem, we can become more aware of the complex layers that are involved and the possible ramifications of any course of action. The analysis should help us to reach an informed decision, but it does not allow us to see into the future. The actual outcome may still come as a surprise.

Part II: Suggested Activities

1. Imagine you are living in the early 1900s. How would you assess the risks and benefits of the automobile from that perspective? How would a risk/benefit analysis of the automobile from today's vantage point be carried out?

2. The city of Victoria has received negative publicity because of their practice of discharging sewage into the ocean. Groups in other cities have protested by cancelling plans to hold conventions in Victoria. The city is not treating its sewage because of cost, and because some scientists believe the ocean's ecosystem can easily handle the amount of sewage released. Discuss the wider implications of this approach to sewage disposal.

3. Nitrites can react in the stomach to produce carcinogenic nitrosamines. Despite this, nitrites are commonly added to cured meats as a food preservative. They prevent the growth of the *Cloristidium botulinum* spores, which produce a dangerous food poisoning known as botulism.

   The botulism micro-organism is the most deadly poison known on earth. Five grams of the toxin would be enough to kill more than one billion people.

   Nitrates occur naturally in many foods, and combined with the bacteria in saliva, they produce nitrites. This means that even if nitrites were eliminated from all cured meats, people would be cutting out only about 22% of their total consumption of nitrites.

   Using this example, discuss with students how a risk/benefit analysis may justify the use of a known carcinogen as a food preservative.

4. Many people engage in practices in their daily lives that carry high risks, even though they are aware of those risks. What factors lead people to justify these actions? Look at this problem in terms of the following practices:

   - taking steroids to enhance appearance and athletic abilities
   - sun tanning
   - riding motorcycles
   - bicycling without a helmet
   - smoking cigarettes

Recommended Resources

1. Alberta Environment publication, *Sewage as a Resource*.
2. Various publications on waste management available from provincial environment departments and municipal waste treatment facilities

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ISBN 1-895350-61-1
PRINTED AND BOUND IN CANADA